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ABSTRACT

The State Planning System (SPS) is presented in the context of a mathematical model used to generate information about the possible impacts of postsecondary education policy decisions. Section I provides an introduction to modeling in higher education management, identifies some current postsecondary education modeling efforts, offers some criticisms of modeling, and presents suggestions for further development of modeling in postsecondary education planning and management. Section II describes modeling activities in several states and suggest criteria for evaluating the potential usefulness of different modeling approaches. Section III describes the SPS as a modeling tool and relates it to other national and state-level modeling activities. A glossary is included containing terms that are associated with the SPS. (Author/CMV)

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MODELING AND THE STATE PLANNING SYSTEM

Technical Report 89

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PREFACE

The State Planning System (SPS) is designed to assist state-level postsecondary education planners in the analysis of issues and problems. The user selects and describes the issue to be addressed, designs the analytical framework that will yield the desired results, selects the variables, assigns values to each, and provides the data. The SPS software and associated documentation help organize the data to support the design. The software then analyzes the data through its simulation and optimization capabilities and provides a flexible set of reporting formats in which to display the results.

The SPS is not a specific model or analytical construct. Rather, it becomes a "model" once the user selects the design that will best address the problem or opportunity to be analyzed. Thus the SPS, which can be used in day-to-day data analysis or to model complex state-level problems, places no a priori requirements on the particular data or design that must be used and can become as many models as the user needs to address a series of issues.

The SPS is designed to be implemented on a wide variety of computer systems with little or no modification. It can operate in interactive or batch mode, is written in ANSI FORTRAN, and has been installed on IBM, Control Data, Honeywell, and UNIVAC computer systems. A fairly large capacity computer system is required since the programs may take as much as 30,000 words of storage.

Installation of the SPS software does not automatically provide the user with the background necessary to fit the SPS to a specific problem. As in any modeling effort, available data and the nature of the selected design relationships may limit the applicability or accuracy of the results. Some staff capability in operations research or computer sciences is useful. Also, users can obtain assistance from NCHEMS staff to initially install the SPS and to help develop the designs necessary to address specific state problems.

The SPS was developed by Dr. Vaughn Huckfeldt (formerly with NCHEMS and now director of the National Policy Analysis Center, Boulder, Colorado) and by Mark Chisholm, Ellen Cherin, and Roger Bassett of NCHEMS. The development process for the SPS began in late 1972 with the National Planning Model project, which was under a contract with the U.S. Office of Education. That initial work resulted in a prototype operational model for use in analyzing the effects of alternative financing plans on access to higher education.

In 1974, development of the State Postsecondary Education Planning Model (SPEPM) was funded under a contract with the National Institute of Education. The developmental work was completed in early 1975 and the software was pilot tested in Colorado, Maryland, and New York in late 1975 and early 1976. The SPS was successfully implemented and used in each of these states and has since been implemented in Oklahoma, Virginia, Minnesota, and South Dakota. In late 1976, the project name was changed to the State Planning System to avoid the confusion caused by the word "model" in the project name.

Major developmental contributions were made by three people outside NCHEMS. Dr. George Weathersby of Harvard University (recently director of the Office of Research for the presidentially appointed National Commission on the Financing of Postsecondary Education) contributed to the planning philosophy of the National Planning Model. Dr. Salvatore Corallo of the U.S. Office of Education added to NCHEMS's knowledge of planning model concepts. And Dr. Leon S. Lasdon of Case Western Reserve University contributed to the development of the nonlinear dynamic optimization algorithm and to the review of the SPS software.

The production schedule for this and other documents related to the SPS was reviewed with the Fiscal Affairs and Operations Committee of the NCHEMS Board of Directors at its October 1976

meeting, and the software and supporting documents have been approved for release by the NCHEMS Board of Directors.

The Center has tested the software to determine that it operates as the documentation indicates. The Center will notify users of any potential problems in the software and will make any necessary changes after initial release. No warranty, expressed or implied, is provided with the software.

The *Introduction to SPS* (NCHEMS Technical Report 86), The *Modeling and SPS* (NCHEMS Technical Report 89), and The *SPS Case Studies* (NCHEMS Technical Report 91) will go to the holders of 1976 subscriptions to NCHEMS publications. All 12 SPS documents (the documents are described and diagrammed inside the cover) and the SPS distribution tape, containing the software and several test designs, can be purchased at cost, either individually or as a set, by any interested party. In addition, implementation assistance for the SPS can be purchased from NCHEMS. This assistance, which based on the pilot-test experience, is strongly advised, can consist of NCHEMS staff days and travel to assist in:

1. Installing the software
2. Conducting a training seminar
3. Conducting a design seminar
4. Assembling data
5. Entering the initial design and data
6. Validating and modifying the intitial design
7. Analyzing the results

The following are NCHEMS documents that are superceded by the SPS documents listed inside the front cover:

Cherin, Ellen; Chisholm, Mark; Huckfeldt, Vaughn; and Smith, Mark. *State Postsecondary Education Planning Model Software System.* Boulder, Colo.: National Center for Higher Education Management Systems [NCHEMS] at Western Interstate Commission for Higher Education [WICHE], 1975.

Chisholm, Mark. *State Postsecondary Education Planning Model Software Documentation.* NCHEMS Technical Report 80. Boulder, Colo.: NCHEMS at WICHE, 1976.

Huckfeldt, Vaughn. *A Preliminary Framework for the State Postsecondary Education Planning Model.* Boulder, Colo.: NCHEMS at WICHE, 1974.

_____. *An Introduction to the State Postsecondary Education Planning Model.* NCHEMS Technical Report 77. Boulder, Colo.: NCHEMS at WICHE, 1976.

_____. *A Design Guide for the State Postsecondary Education Planning Model.* NCHEMS Technical Report 78. Boulder, Colo.: NCHEMS at WICHE, 1976.

_____. *State Postsecondary Education Planning Model Training Manual.* NCHEMS Technical Report 79. Boulder, Colo.: NCHEMS at WICHE, 1976.

Huckfeldt, Vaughn; Cherin, Ellen; and Chisholm, Mark. *State Planning System Case Studies.* NCHEMS Technical Report 81. Boulder, Colo.: NCHEMS at WICHE, 1976.

Huckfeldt, Vaughn; Cherin, Ellen; and Chisholm, Mark. *State Planning System Data Procedures.* NCHEMS Technical Report 82. Boulder, Colo.: NCHEMS at WICHE, 1976.

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The State Planning System (SPS) is the result of the combined efforts of many individuals. In particular, the representatives from the SPS pilot-test states were most helpful in their use of earlier test versions of the software, and in providing their guidance, review comments, and suggestions concerning documentation. Since each pilot-test state user was required to develop a specific set of design relationships for a particular problem, the extent of their efforts went beyond the normal pilot-test commitment and deserves special acknowledgement. Those involved from each of the states were:

Colorado Commission for Higher Education:
- Dr. Frank Abbott, Executive Director
- Dr. William Adrian
- Mr. Edward Lyell
- Mr. Carleton Ekberg

Maryland State Board for Higher Education:
- Dr. Sheldon H. Knorr, Commissioner of Higher Education
- Mr. John E. Clayton
- Dr. Stephen R. Hample
- Mr. B. Kerry Gustafson

New York Department of Education:
- Dr. William Fuller, Associate Commissioner
- Dr. Paul Wing
- Mr. Michael Cruskie
- Dr. Shimon Awerbuch
- Mr. Steve Cohen
- Ms. Jackie Skolnik
- Ms. Judy Hutchison

Significant ideas for the construction of the SPS were provided by Kent Weldon and Mark Smith of NCHEMS. Kent Weldon worked on the development of the National Planning Model and made many valuable suggestions regarding the SPS, and Mark Smith worked on the development of an early pilot-test version. Dr. Melvin D. Orwig has been the NCHEMS Associate Director responsible for the SPS since June 1975, and his guidance and patience are most appreciated. Other staff at NCHEMS who have contributed to the development of the SPS are Dr. Allan Service, Dr. Kent Caruthers, Dr. Robert Gray, Marilyn McCoy, and David Makowski.

The production of the SPS documents has been a lengthy and difficult task, and special thanks are extended to Cynthia Labuda for her work in preparing the tables, figures, and charts, coordinating the lengthy process of draft production, as well as typing the documents. Additional acknowledgements are given to: William Johnston, Jean Strueber, and Maureen Byers for editorial assistance, Clara Roberts for assisting in the overall coordination of the document production, Elizabeth Peto for typesetting several of the documents, and Paula Dressler for typing several early drafts of the SPS documents. Many other people, too numerous to mention, were involved in the project at one time or another, and their help has also been appreciated. It should be emphasized, however, that any mistakes or errors in the documents are the sole responsibility of the authors.

I

MODELING

Introduction

Much has been written about models and modeling. The postsecondary education analyst has access to an increasing number of models to speed up, expand, and otherwise improve the analytical effectiveness of postsecondary education management and program planning. As the 1980s approach, forecasts of declining enrollments and revenue uncertainties increase the importance of informed, systematic, sensitive handling of highly interrelated policy and operating issues.

How shall scarce resources be equitably distributed among competing institutions of postsecondary education? What obligations or opportunities do state-level postsecondary education agencies have to supervise fund distribution in ways that satisfy public expectations for coordinated delivery of postsecondary education services? What impact will declining enrollments have on various legal commitments to faculty tenure and collective bargaining? What impacts are scarce resources having on implicit and stated goals regarding access and program availability in each state?

Models and modeling can contribute to the analysis of these and similar issues. The question to the analyst is, What model or modeling technique best suits the issues to be addressed, the staff capabilities of the agency, and the commitment of agency and analyst to systematic analysis of policy issues?

The purpose of this document is to present the State Planning System (SPS) in the context of models and modeling. This first section provides an introduction to modeling in higher education management, identifies some current postsecondary education modeling efforts, offers some criticisms of modeling, and presents suggestions for further development of modeling in postsecondary education planning and management. The second section describes modeling activities in several states and suggests criteria for evaluating the potential usefulness of different modeling approaches, and the third briefly describes the SPS as a modeling tool and relates it to other national and state-level modeling activities.

Modeling and Postsecondary Education Management

Analysis with modeling support differs from the same analysis without modeling support mainly in the ability of the analyst to more fully observe and consider the interrelationships at work. Trend-line enrollment forecasts can be accomplished with a straight-edge and a pencil. But trend lines are influenced by tuition increases, legislative appropriations, and student financial aid proposals. Each of these influences in turn involves decisions within the control of state legislatures or postsecondary education agency officials—human beings for whom intuitive judgement and political trade-offs weigh heavily in arriving at a final decision.

It is in support of this intuitive, political process that modeling makes its strongest contribution to postsecondary education management. Modeling provides tests of decision alternatives—tests that can help the decision maker determine which alternative best matches the political environment and the decision maker's "feel" for the situtation.

Basic operations research texts define modeling as a predictive technique.[1] In particular, models are used to predict how part or all of a real world system operates under different sets of assumptions provided by the modeler. Real world systems are usually too difficult and too costly to manipulate, but if the system can be modeled, new or changed policy variables can be tested for impact before they are implemented.

The predictive nature of models does not imply that they have no value in historical analysis. Historical cost studies are an example of the use of models to better visualize historical relationships. The NCHEMS Costing and Data Management System (CADMS) is an example of a model which displays historical cost data in a framework more suitable to cost analysis than the framework embodied in most institutional or state-level postsecondary education accounting systems.

[1] See, among others, Samuel B. Richmond, *Operations Research for Management Decisions* (New York: The Ronald Press Company, 1968).

Most current, on-going uses of modeling in postsecondary education support the estimation of budget requirements and the allocation of resources among institutions within a single system. Cost studies, enrollment analyses and forecasts, and the development of budget formulas are all examples of budget-related modeling activities.

There is increasing use of modeling in more general postsecondary education policy analysis, particularly as part of the planning and review responsibilities of state-level coordinating and governing agencies. The analysis of the impacts of alternatives to current tuition levels and charging practices is one example.[2] Analysis of the impact of revenue fluctuations on the proportion of tenured to non-tenured faculty is another.

But in each case, the principle is the same. The model should help the analyst visualize and replicate the interrelationships of a real system. And the level of complexity should be sufficient to generate results similar to those that would occur if the intended action was implemented in the system. To support that purpose, the logic of the model must be simple and the capacity of the model must accommodate multiple relationships—as many relationships as can be supported by available data, staff, and machine capacity, but (for the sake of efficiency) no more than are necessary to approximate the actual working relationships of the real system.

In the remainder of this section, a few national modeling efforts will be identified, some criticisms of modeling will be discussed, and some suggestions will be offered regarding further developments in the modeling field.

Major National Efforts

It is neither feasible nor useful to attempt here an exhaustive inventory of all known modeling efforts in the field of postsecondary education management. Neither is it the intention of NCHEMS to evaluate the effectiveness of available models. Selection of a model by a postsecondary education institution or agency remains a matter of a very careful match-up between an identified analytical need and the model that best serves, or can be adapted to serve, that need.

[2]See the *SPS Case Studies* document.

Modeling efforts can be placed in categories based upon such things as degree of generalizability (adaptability to *any* institutional or agency setting versus development for *a specific* institutional setting or analytical requirement), sponsorship (private versus public), scope of the relationships represented in the model (modeling a specific relationship, for example, course loading, versus modeling the entire institution or system), and time perspective (historical cost analysis versus prediction of future resource requirements or patterns).[3]

For the purposes of this section, the discussion will be limited to public and private, generalizable, computerized simulation models of the entire institution or system. Six examples are offered. Under private sponsorship are the Comprehensive Analytical Methods for Planning in University Systems (CAMPUS) supported by Systems Dimensions Limited (SDL) of Canada; Peat, Marwick and Mitchell's SEARCH; and Midwest Research Institute's HELP/PLANTRAN. In the public domain are the Statewide Planning and Budgeting System (SPBS) developed by Robert Huff, and the Resource Requirements Prediction Model (RRPM) and the State Planning System (SPS), both developed by NCHEMS.

RRPM, CAMPUS, and SEARCH are institutional cost simulation models, each intended to help identify the faculty, staff, space, and dollar consequences of a given set of enrollment factors. The SPBS is a fund-distribution model intended to help state-level officials distribute funds among public institutions in a way that recognizes differences in need and resource requirements among programs, instructional levels, and institutions. HELP/PLANTRAN and the SPS are modeling frameworks. HELP/PLANTRAN is marketed as an institutional management tool. The SPS has been marketed as a tool for state-level use, primarily to support analysis of the tradeoffs among potentially competing state-level postsecondary education goals. NCHEMS plans to test the SPS in an institutional setting during 1978.

[3]For further discussion of modeling categories, see Roger N. Gaunt and Michael J. Haight, "Planning Models in Higher Education Administration," *Journal of Education Finance* 2 (Winter 1977): 305-323.

RRPM, CAMPUS, and SEARCH are similar in nature. As with any computerized cost-simulation model, they have relatively large data requirements, are computerized, and are relatively expensive to implement. Each has been developed in response to demands for more disciplined ways of analyzing cost patterns and displaying and simulating costs in degree-program and functional categories that are not usually a part of postsecondary education accounting systems. They are relatively difficult to adapt to more comprehensive planning purposes.

The SPBS provides an analytical framework and discipline to support analysis of differential needs and resource requirements at the state level. It remains to be seen whether the need for a state-level planning and budget analysis framework is similar enough among the states to warrant widespread adoption of the SPBS.

HELP/PLANTRAN is an institutionally oriented modeling language designed to allow institutions, even small institutions, to model the institutional resource planning and allocation process. It is similar to RRPM, SEARCH, and CAMPUS except in its scope and in the extent to which the institutional user specifies the modeling relationships.

The SPS is a state-level oriented modeling framework intended to allow analysis of the complex relationships among postsecondary education goals and the impact of a change on each goal. It can effectively use existing data sources and can be implemented with the staff capabilities of most state agencies and medium- to large-size institutions.

Selecting a Model

Any analyst, institution, or agency contemplating development or purchase of an analytical model should take the time to look at all such models available and then select the best approach based upon such criteria as the following:

1. *Match between the flexibility of the model and the variety of uses comtemplated.* A single-purpose model usually offers more analytical power than a more flexible model or modeling framework. But the advantage is gained only if the match between purpose and model is very carefully considered before the model is designed or purchased.
2. *Match between staff capabilities and model maintenance requirements.* If extensive involvement is required to build or adapt model designs, the effort may be beyond the staff capabilities of some agencies or institutions.
3. *Availability of data.* Most modeling efforts operate on a time schedule that prohibits the collection of new categories of data, so the scope and usefulness of a modeling application is largely defined by existing data. Some modeling packages can be easily adapted to existing data. But any adaptation involves some loss of scope and accuracy of results and must be carefully assessed by the modeler.

Criticisms of Modeling[4]

Modeling, like any other area in the management sciences, is subject to criticism in terms of the discipline with which it is developed and the uses or misuses that are made of it. Systematic approaches to management analysis are usually justified by promises of more efficient processes and reduced administrative costs. But it is difficult to identify the costs involved in a systems application and to place a value on the results. So there are frequent and reasoned criticisms of the proper use of modeling in postsecondary education management.

Perhaps the most frequent criticism is the image of sophistication that characterizes most models. A model can be beyond the comprehension of some of those involved in the decisions it supports. If it is, the modeling results will be viewed with suspicion by those who don't understand it, and set aside in favor of less sophisticated, more intuitive, or political decision factors. In a decision environment as political as that of higher education today, rational or sophisticated analyses often fare poorly, and the model can become the scapegoat whenever its results have less impact than expected.

Ironically, modeling also suffers from criticism that it is not sophisticated enough—that a model never captures all components and variables of the institution or process it is intended to represent.

[4]See also G. Ben Lawrence and Allan L. Service, eds., *Quantitative Approaches to Higher Education Management* (ERIC/Higher Education Research Report No. 4, 1977); Wayne F. Kirschling, "Models: Caveats, Reflections and Suggestions," in *Assessing Computer Based Systems Models* (New Directions for Institutional Research No. 9, Spring 1976); and Steven P. Dresch, "A Critique of Planning Models for Postsecondary Education: Current Feasibility, Potential Relevance and a Prospectus for Further Research," *Journal of Higher Education* 46 (May/June 1975).

From the user's point of view, relationships omitted from a model design must somehow be recognized when results are interpreted. And interpretation of results is a subjective process which can scatter the focus of the more objective modeling process.

Lack of realism is a criticism made by both decision makers and researchers. Most successful decision makers count on their own sense of reality as an important part of the decision process. When a model produces alternatives that cannot be practically achieved, the decision maker often blames the model. Researchers worry about lack of realism for different reasons, noting that the convenience of a model allows the analyst to reach decisions too quickly, obscuring incomplete research or faulty model designs, and counting too heavily on the model builder's sense of the relationship being modeled.

The rigidity or single-purpose nature of some models is generalized to all modeling efforts by some critics. Most blame for model rigidity follows from attempts to present a given model as being more flexible than it really is. Single-purpose models are important to repetitive analytical routines such as cost studies and course-loading patterns. More flexible modeling packages provide better support to the work of an agency or staff unit charged with a variety of policy studies.

Modeling is expensive. Those who base their criticism of modeling on its costs are influenced by the add-on nature of those costs. Modeling expertise is usually purchased from outside sources and one such budget commitment is all that many agencies or institutions can afford in an entire year. But viewed in terms of the alternatives—doing without knowledge of the relationships captured in the model, or hiring more staff analysts to do a job that could be done more efficiently with a model—it may appear less costly.

Finally, much of the general criticism of modeling is based on the lack of disciplined research to back up modeling relationships. Many argue that models are developed as a way of covering up uncertainties and qualifications that would be emphasized by a researcher or a specialist in the area being studied. This problem is aggravated by the tendency of decision makers to quickly accept modeling results that match their own intuitive preferences, ignoring or being unaware of how well the internal relationships of the model represent the relationship being modeled.

Most of these criticisms can be viewed as constructive warnings to the analyst about implementing a modeling exercise. Any potential modeler should know the relationship to be modeled well enough to judge the consequences of omitting some of its elements from the model. The model should be developed and tested in a way understandable to those who will use it. It should serve to identify rather than obscure areas that require further research.

Directions for Further Development

Modeling, as one aspect of the management sciences, has too little cohesiveness to be discussed as a single, coordinated effort. Thus it is difficult to recommend specific developmental proposals, but some developmental concerns certainly need more emphasis.

Postsecondary education, especially at the state level, contains too many site-to-site differences to warrant development of a comprehensive postsecondary education model. Certain elements of postsecondary education management (cost analysis and resource allocation among them) are similar enough to justify the development of single-purpose models. Certain policy issues (the tradeoff between tuition levels and access goals, for example) lend themselves to the development of issue-specific models.

But what appears to be more important than the development of more models is an improvement in modeling processes. Visualization of the issue to be analyzed, formulation of preferred analytical approaches, analysis of the tradeoffs between model complexity and data support costs, user/modeler working relationships, and interpretive and reporting skills are all vitally important to a successful modeling effort.

So long as the user's involvement in modeling is limited to selection of a model or modeler and is influenced by fascination with the computer magic that models so ably display, the necessary reconciliation between the user's analytical needs and the nature and size of the model will be incomplete.

Further development of research support of modeling is also needed. Operations researchers are already doing their part, but more attention needs to be given to researching the behavior of the individual factors and relationships upon which models depend. Studies of the responsiveness of enrollment levels to changing tuition and of the responsiveness of faculty to changing workloads are examples of research efforts that could help modelers more accurately describe the tradeoffs involved in many of the major postsecondary education policy issues we now face.

SOME STATE EDUCATIONAL MODELING EFFORTS

The Results of an Invitational Seminar

This section is a summary of the results of an invitational seminar sponsored by the Education Commission of the States (ECS) and the National Center for Higher Education Management Systems (NCHEMS) in February 1976. The purpose of the seminar was to discuss educational modeling efforts underway at the state level. As part of the seminar proceedings, each state provided a description of its own modeling efforts. Those descriptions are a part of this summary as are the results of a discussion on criteria that might be used to evaluate state-level modeling efforts.

The seminar was attended by policy and technical representatives from eight states and several national researchers with state-level educational modeling experience. Its purpose was to facilitate communication among states on the use of modeling to support state-level postsecondary education analysis. The eight states attending the seminar were Colorado, Illinois, Maryland, New Mexico, New York, Tennessee, Virginia, and Washington. A brief description of each state's experience with different models follows.

- The Colorado Commission on Higher Education reported on two state-level and two institutional-level models. EXIR-OMNITAB links an information retrieval system (EXIR) to a statistical analysis package (OMNITAB). The result is a framework and modeling language for the development of models for one-time studies and for some analyses of an ongoing nature. The second state-level modeling effort used the NCHEMS State Planning System (SPS) to examine the impact of several different proposed changes in tuition policy. At the institutional level, CAMPUS/COLORADO was basically the CAMPUS VI program (developed by Systems Research Group) modified to work within existing Colorado postsecondary education definitions and planning/budgeting structures. The NCHEMS RRPM was used by four institutions to support master planning, program evaluation, and faculty and staff assignment processes. The Colorado Commission was involved in both institutional efforts, assisting in the development of common definitions and in certain technical aspects of model implementation.

- Illinois used The National Commission on the Financing of Postsecondary Education (NCFPE) model, as modified by Systems Research, Inc., to forecast enrollment by college sector and level, using student family income and ability characteristics and various assumptions about tuition and student financial aid policies.

- One of the Maryland modeling projects used an internally developed Enrollment Projection Model to forecast annual enrollments by public/private, graduate/undergraduate, two-year/four-year/university, and full-time/part-time. In a second effort, Maryland used the NCHEMS SPS to develop a systematic process by which alternative staffing, financing, and capital expenditure plans can be examined in relation to each other and to projected enrollments.

- New Mexico's Cost Model was designed to explain cost variations based on unit cost information for six colleges. The information produced includes average salaries by rank and cost center, average teaching load, average class size, and faculty rank distribution.

- New York's internally developed Enrollment Projection Project produced enrollment estimates for each of the higher education institutions in New York. In another effort, New York evaluated the NCHEMS SPS as an example of a large-scale quantitative model that could be used to develop financing strategies for higher education in New York.

- Tennessee, like Illinois, evaluated The National Commission on the Financing of Postsecondary Education (NCFPE) model to determine the extent of modifications necessary for it to acceptably predict the effect of tuition and financial aid policies on enrollments in higher education.

- Virginia used a modification of the CAMPUS VIII model (developed by Systems Dimensions

Limited) to (1) emulate new budget requesting procedures, (2) estimate projected personnel service requirements for the 1976-78 budget using various staffing and salary options, (3) estimate projected nonpersonnel service requirements for the 1976-78 budget using various inflation and relational options, and (4) analyze projections, requests, and recommendations.

- And finally, Washington, with the assistance of Boeing Computer Services, constructed a model to support a unit expenditures study for all public postsecondary education institutions in the state. The model is intended to relate all institutional costs back to the instruction, research, and public service program budget categories and to attempt to determine marginal costs.

Some Common Threads

What follows represents the opinions and estimates of staff in the eight states represented at the February 1976 seminar. It is offered as a general indication of how useful and demanding each of the described modeling efforts was in the state in which it was implemented.

Table 1 displays the major uses served by the modeling efforts described above. The major areas of emphasis among the eight states are the analysis of financing plans, enrollment forecasting, and planning faculty and staff resources. Manpower planning, program planning, and program evaluation were not active issue areas among the eight states represented at the seminar.

Tables 2 and 3 show that, in most of the states, an external agency contributed the original model design, helped to adapt the original design to unique state needs, or assisted the state agency in some other way. In the three SPS pilot-test states, the software was provided by NCHEMS but the state agency was responsible for the development of the actual design. In slightly more than half of the modeling efforts, some percentage of the analysis was done by the staff of an external agency.

Table 4 suggests no pattern regarding intended frequency of use. It is interesting to note that in terms of development, analysis, and frequency of use there appears to be no relationship between the involvement of external agencies and the complexity and size of the model developed. The

Table 1

Problem Areas Being Investigated by State Educational Models

State and Model	Manpower Planning	Program Planning	Program Evaluation	Enrollment Forecasting	Faculty/ Staff/ Planning	Financing Plan Analysis	Facilities/ Space Capital Planning	Other as Specified by States
Colorado –EXIR/OMNITAB		X	X	X	X	X	X	X
Colorado –SPS						X		X
Illinois –NCFPE Access				X		X		
Maryland –Enrollment Projection Model			X					
Maryland –SPS					X	X	X	
New Mexico –Cost Model								X (Cost Analysis)
New York –Enrollment Projection Project				X				
New York –SPS						X		
Tennessee –NCFPE Model						X		
Virginia –CAMPUS					X	X		
Washington –Budget Model								X (Budget)
The following are institutional applications of modeling as reported by the state agency coordinating the effort:								
Colorado –CAMPUS/ COLORADO	X	X			X	X	X	
Colorado –RRPM					X	X		

models receiving external assistance in development and analysis range from the very simple and small (such as the NCFPE model tried by two states) to the very complex and large (such as the use of CAMPUS by Virginia and Washington's budget model). And the relatively complex enrollment projection model, which uses logistic curves to fit each projection to historic ratios for several types of students, was developed with internal staff capabilities in Maryland.

In only one instance, detailed in Table 5, was a high level of technical competence required to use the model. Different perspectives of similar models are shown in Colorado's institutional-level application of CAMPUS (perceived as requiring a high level of competence) as compared to Virginia's state-level use of CAMPUS. A similar difference occurs in perceptions of the NCFPE model by Illinois and Tennessee, while there appears to be more general agreement that relatively less technical competence is required to use the SPS. It also appears that the cost and budget models require more technical competence than the more general financial planning models.

The data regarding project success in Table 6 may be biased since the respondents, for the most part, are also the project directors. No state ranked the project as a complete failure and most of the respondents ranked project success at the higher end of the scale.

The cost estimates in Table 7 should be examined with the caveat that modeling costs are difficult to estimate. The range in costs is due in part to the range of complexity among model designs and in part to the computer system being used. Note, for example, the range of the cost per run for Virginia using the CAMPUS model. The summary does indicate that the states involved have been willing to invest a substantial amount of staff and computer resources in the modeling effort.

Some Potential Evaluative Criteria

Another topic discussed at the seminar concerned criteria for evaluation of models intended to support state-level analytical requirements. An initial list of suggested criteria was proposed by the NCHEMS staff. Seminar participants discussed the proposed set and several more were then added

Table 2

What Organization Developed the Model?

State and Model		Internal Development by the State Agency	NCHEMS	Other
Colorado	–EXIR-OMNITAB	X		National Bureau of Standards, University of Colorado–Biology Department/Taximetrics Laboratory
Colorado	–SPS	X (Design)	X (Software)	
Illinois	–NCFPE Access			NCFPE modified by Systems Research, Inc.
Maryland	–Enrollment Projection Model	X		
Maryland	–SPS	X (Design)	X (Software)	
New Mexico	–Cost Model	X		
New York	–Enrollment Projection Project	X		
New York	–SPS	X (Design)	X (Software)	
Tennessee	–NCFPE Model			NCFPE
Virginia	–CAMPUS			Systems Dimensions Limited
Washington	–Budget Model	X		Boeing Computer Services
The following are institutional applications of modeling as reported by the state agency coordinating the effort:				
Colorado	–CAMPUS/COLORADO			Systems Research Group
Colorado	–RRPM		X	

Table 3

What Percent of the Analysis Was Completed by Staff of an External Agency

State and Model		Staff in the State Agency	Staff of an External Agency
Colorado	–EXIR-OMNITAB	100%	
Colorado	–SPS	50%	50%
Illinois	–NCFPE Access	100%	
Maryland	–Enrollment Projection Model	100%	
Maryland	–SPS	50%	50%
New Mexico	–Cost Model	75%	25%
New York	–Enrollment Projection Project	100%	
New York	–SPS	100%	
Tennessee	–NCFPE Model	50%	50%
Virginia	–CAMPUS	75%	25%
Washington	–Budget Model	75%	25%

The following are institutional applications of modeling as reported by the state agency coordinating the effort:

Colorado	–CAMPUS/COLORADO	50%	50%
Colorado	–RRPM	10%	90%

Table 4

How Frequently Is the Model Used?

State and Model		One-Time Study	Yearly	Monthly	Other
Colorado	–EXIR-OMNITAB				X (Often)
Colorado	–SPS		X		
Illinois	–NCFPE Access	X			
Maryland	–Enrollment Projection Model		X		
Maryland	–SPS				X
New Mexico	–Cost Model		X		
New York	–Enrollment Projection Project		X		
New York	–SPS	X			
Tennessee	–NCFPE Model	X			
Virginia	–CAMPUS			X (July-Dec. '75)	X (Spring '76)
Washington	–Budget Model				X (Biannually)

The following are institutional applications of modeling as reported by the state agency coordinating the effort:

Colorado	–CAMPUS/COLORADO	X			
Colorado	–RRPM				X (Semester)

Table 5

Level of Technical Competence Required To Use Each Model

State and Model	None	1	2	3	4	5	Very Great
Colorado –EXIR-OMNITAB			X				
Colorado –SPS			X				
Illinois –NCFPE Access					X		
Maryland –Enrollment Projection Model			X				
Maryland –SPS			X				
New Mexico –Cost Model					X		
New York –Enrollment Projection Project					X		
New York –SPS				X			
Tennessee –NCFPE Model			X				
Virginia –CAMPUS				X			
Washington –Budget Model					X		

The following are institutional applications of modeling as reported by the state agency coordinating the effort:

Colorado –CAMPUS/COLORADO						X	
Colorado –RRPM				X			

Table 6

How Successful Was the Project?

State and Model	Complete Failure	1	2	3	4	5	Very Successful	Will the Model Be Used Again?
Colorado –EXIR-OMNITAB						X		Yes
Colorado –SPS						X		Yes
Illinois –NCFPE Access			X					No
Maryland –Enrollment Projection Model						X		Yes
Maryland –SPS			Not completed					Yes
New Mexico –Cost Model					X			Yes
New York –Enrollment Projection Project				X				Yes
New York –SPS					X			Yes
Tennessee –NCFPE Model				X				N/A
Virginia –CAMPUS					X			No
Washington –Budget Model					X			N/A

The following are institutional applications of modeling as reported by the state agency coordinating the effort:

Colorado –CAMPUS/COLORADO						X		No
Colorado –RRPM					X			Yes

Table 7

Estimate of the Cost of the Project

State and Model		Number of Professional FTE Staff	Number of Months Duration	Total Computing Cost	Cost Per Run
Colorado	–EXIR-OMNITAB	5	18	$30,000	$.50-$100
Colorado	–SPS	.25	3	$ 2,000	$100
Illinois	–NCFPE Access		12	$ 2,000	$5-$10
Maryland	–Enrollment Projection Model	2	.5	$ 100/yr	$2-$3
Maryland	–SPS	2	3		$5-$100
New Mexico	–Cost Model	3	on-going	$50,000/yr	$500
New York	–Enrollment Projection Project	.25/yr	2/yr	$ 2,000	
New York	–SPS	1.5	12	$10,000	$75
Tennessee	–NCFPE Model	1	3		
Virginia	–CAMPUS	2	6	$18,000	$150–using Virginia installation $700-$1000 -- using SDL installation
Washington	–Budget Model	1	8		$1,000-$1,500
The following are institutional applications of modeling as reported by the state agency coordinating the effort:					
Colorado	–CAMPUS/COLORADO	8	24	$40,000	$250
Colorado	–RRPM	5	12		$50

to the list. The result is intended to guide state-level and other model users in the task of planning and evaluating agency modeling efforts.

The criteria are listed in the rank-order preference of the conference participants. The number in parentheses beside each criterion indicates the importance the seminar participants attached to it, with a value of 9 meaning great importance and a value of 1 meaning little importance as a basis for planning or evaluating a modeling effort. It is interesting to note in examining the list that 11 of the possible 17 criteria rank in the top half of the weighting scale. In addition, the criterion "Low Cost" is one of those ranked fairly low. This may suggest that once the criteria ranked at the high end of the scale are satisfied, then cost is of less importance. Some states are also able to use institutional computer facilities at little or no direct cost.

The lowest ranked criterion, "Optimization as well as Simulation," was added by the conference participants. It may have achieved this low rating because most states have little experience in using the optimization capability. (The SPS is the only model among those implemented by the states that has this capability.)

The list of criteria follows:

1. (8.6) *Confidence in the Accuracy of the Results*—the results from the model are of sufficient accuracy to be used with confidence by policy and quantitative personnel.
2. (7.5) *High Priority Issues*—the policy issue addressed is of sufficient priority to justify the modeling effort.
3. (6.2) *Uses Existing In-House Data*—the data needed for the model can be assembled or derived from in-house data; no new data collection is required.
4. (6.0) *Those Involved with Implementing the Model Results Have Been Informed during Each Step of the Development and Use of the Model.*
5. (5.9) *Understandable and Acceptable Relationships*—the equations used to calculate the results are easily understood and acceptable to policy and technical personnel.
6. (5.1) *Summary Reports with Detailed Information Available*—the policy maker can review summary reports for which detailed backup information is available.
7. (5.0) *Understandable Reports*—the reports

available directly from the model can be easily read and understood by the policy maker originating the policy question.

8. (5.0) *Executive/Political Support and Awareness*—all of the different political factions have been informed of the use of the model in the policy analysis and have supported such a study.
9. (4.8) *Flexibility*—the relationships and/or reports can easily be modified.
10. (4.7) *Technical Staff Availability and Continuity*—sufficient personnel with quantitative background are available during the full duration of the project.
11. (4.6) *Acceptable Response Time*—the time between the initial policy question and the resulting reports should be acceptable to the policy maker.
12. (4.1) *Consideration of Resource and Political Constraints*—the model can accommodate perceived resource and political constraints.
13. (3.7) *Low Cost*—the cost of each policy analysis report can be obtained at one-half the price the policy maker would have been willing to pay for such a report.
14. (2.6) *Model Can Be Run by Staff without Sophisticated Background in Modeling.*
15. (2.4) *Availability*—can be used by more than one agency independently.
16. (2.1) *Model Results Remain Realistic over a Wide Range of Input Values*—for example, the results should be as acceptable for a variable change of 1% as for a change of 50%.
17. (2.0) *Optimization as well as Simulation*—the model should be able to estimate decision values that would probably achieve goals as well as calculating possible impacts of inputs.

III

THE STATE PLANNING SYSTEM AS A MODELING TOOL

Capabilities and Limitations of the SPS

The State Planning System is not a model. Rather it is a modeling framework which, in the hands of a skilled analyst, provides the structure, routines, and calculations necessary to develop a separate design (or model) for each appropriate analytical requirement of the agency or institution.

It is flexible. A wide range of postsecondary education issues and levels of complexity are within its capabilities. It is best suited for simulation and optimization analysis of conflicting or otherwise interrelated postsecondary education goals and planning issues. It is most feasible at relatively high levels of aggregation. And it is designed to be implemented on a wide variety of computer systems with little or no modification.

The SPS is designed to get maximum mileage from existing data. Its file structure assists the user in the task of identifying and organizing the data needed to support a given design. The user must decide the tradeoff between limits on available data and limits on the precision of the results of the design.

The SPS encourages, even requires, a relatively high level of user involvement. The user must understand the issue to be modeled before work on an SPS design begins. The user specifies all design relationships and data files, leaving to the SPS only the simulation and optimization algorithms and the data reporting routines. The more thoroughly the user understands the issue and the design, the easier it is to modify the design to develop alternative results or to further explore some aspect of the design relationships.

The two most significant limitations on use of the SPS are staff and computer center capabilities. A third limitation relates to agency priorities and interests in modeling as an analytical tool.

The pilot-test experience with the SPS suggests that most state-level agency staff, if they receive some training in specifics of the SPS, can operate the software. The best results have occurred in agencies with staff skills in policy analysis and in operations research or the computer sciences. Familiarity with FORTRAN is also an advantage.

Also, most agencies with issues complex enough to justify a modeling approach have access to sufficient computer capacity to support most SPS designs. Since all relationships and data for one design must fit within available computer storage simultaneously, a design addressing a large or very complex set of relationships or a design addressing a high level of detail within a few relationships may exceed available capacity. In the pilot-test experience so far, designs have been adjusted to computer capacity with no appreciable loss of preferred results.

The SPS Software

The SPS consists of three modules and five file types.

- The Simulation and Optimization Module (SOM) is the computational module for the SPS. The SOM performs the calculations specified in the design by the user, produces on request certain reports related to the simulation and optimization calculations, and creates a new data base containing the results of the current run of an SPS design.

- The Data and Report Module (DRM) is the data manager and report writer for the SPS. DRM is used to create the data values and output labels used in an SPS design and to produce reports and plots from the results of SOM runs. It can also produce summaries of the data values and output labels for a design, list the variables and basic design characteristics for a given design, update the design values for a new SOM run, and subdivide or re-sort the data values and labels as necessary during a series of runs.

- The primary use of the Merge Module (MRG) is to append the results of several runs of SOM together so that the DRM can produce reports comparing the runs.

The three operating modules within the software are supported by five types of files.

- The design subroutines (DS) file contains the actual design relationships developed by the user to address a specific issue. The DS file contains three FORTRAN subroutines provided by the user. These routines are called by SOM when a run is made.

- The data base (DB) file contains all the data values to be used by a design. The user determines the data values most appropriate and available for a design and displays them in the structure provided by the DB file. Each data value is identified by the time periods to which it relates, by the variable with which it is associated, by the design sector it serves, and by the number of the SPS run to which it relates.

- The description (DC) file contains the labels or descriptions used to identify the output of an SPS design. Each of the labels is provided by the user so that SPS report formats can be as familiar as possible to all who are working with the results of a given SPS design.

- The design (DF) file defines or describes an SPS design. It includes the number of variables, the number of planning periods, the characteristics of the basic design, and the labels for the SOM and DRM. The actual design calculations and commands are contained in the Design Subroutines file. The DF file serves primarily as a record of a given design.

- The sector communication table (SCT) is used in some designs to pass information from one design sector to another during either a simulation or an optimization run. The SCT provides a structure within which the user can specify the data values to be passed between sectors.

The following figure displays the primary relationships among the modules and files described above. The Merge Module (MRG) and the sector communications table (SCT) are not displayed because they have rather specialized uses. The existence of two data base files (Input Data Base and Output Data Base) illustrates the use of as many separate DB files as necessary to separately record and save the main data base produced during a run plus all others selected for retention by the user.

The Relationship between the SPS and Other National Modeling Efforts and State Modeling Practices

The SPS is not a substitute for the analytical detail provided by the major fixed models. RRPM, CAMPUS, and SEARCH are designed to work in specific analytical areas (resource allocation and cost simulation) at a level of detail too great for cost-effective duplication within the SPS framework. The high level of user specification of design relationships required within the SPS provides more flexibility but at a cost in terms of the computer capacity necessary to complete a run.

The SPS does respond to many of the criticisms of modeling, especially those calling for analytical rigor and user responsibility in the design and evaluation of a specific model. It is not possible to make effective use of the SPS without thoroughly understanding its strengths and limitations and the interrelationships involved in the issue to be analyzed. But the high degree of staff involvement required by the SPS does much to dispel the mystique that surrounds many modeling applications.

The SPS is just as vulnerable to criticisms related to incomplete research as any other model or modeling technique. But the development of an SPS model involves much conscious choice or control over the design, allowing the analyst to rely less on design components that have not been completely researched and to know better when and in which of its components the model offers less than a complete picture of the issue being analyzed.

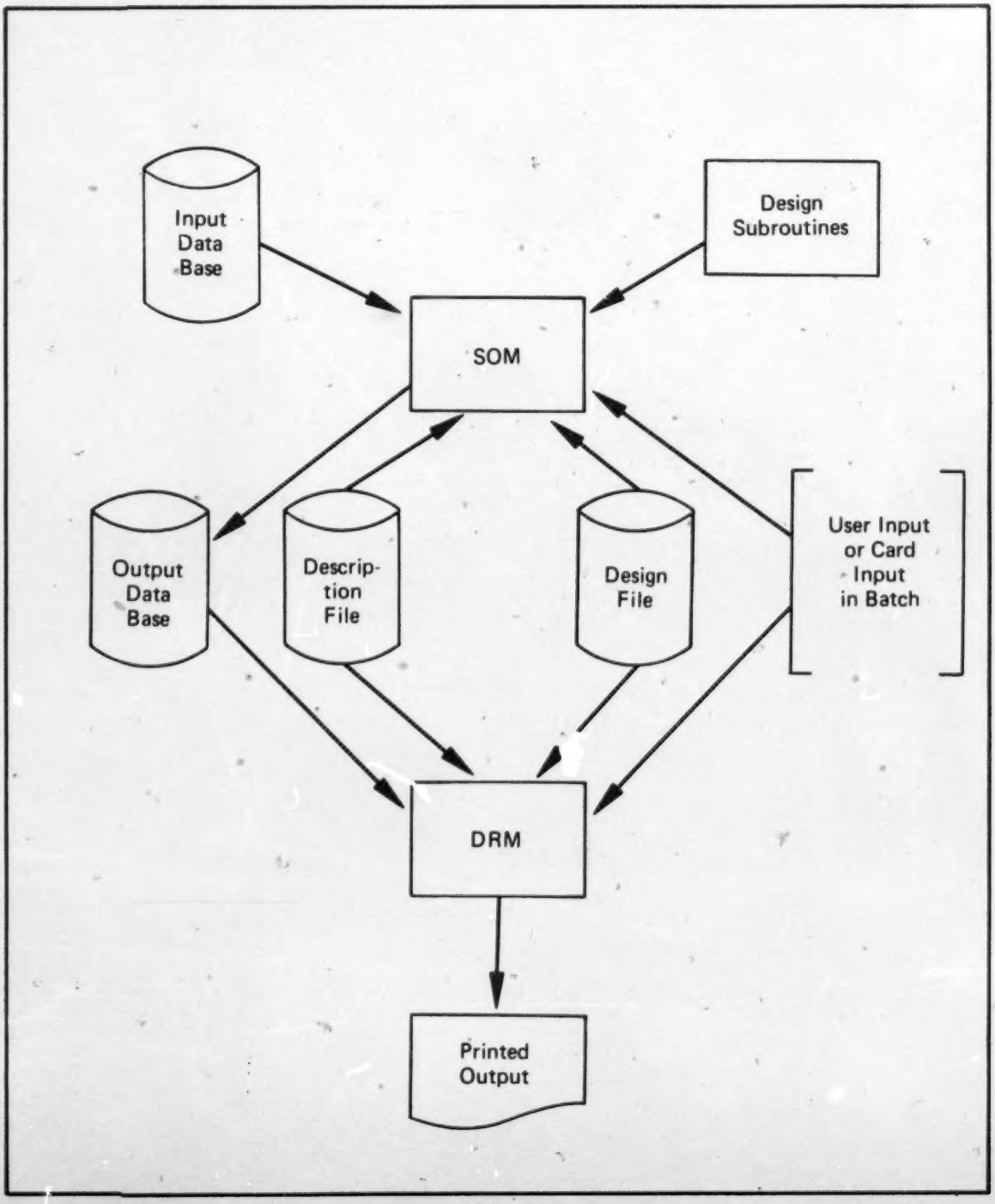
The SPS is not expensive. Even in the relatively expensive optimization mode, it can be implemented within resources available to most users with responsibilities complex enough to warrant its use.

Finally, most of the analytical tasks described by the eight states that participated in the effort described above can be duplicated with the SPS. In fact, three of them were pilot-test applications of the SPS. In considering which resource to use in a modeling application, each state (and any other user) needs to assess existing staff capabilities, the analytical agenda of the agency, and the com-

puter capacity available to support the SPS. The results of such an analysis will not always recommend the SPS. But—and this is the value of a flexible modeling framework over a fixed model—the SPS can be used for a wide range of modeling applications.

Figure 1

The SPS Software



Glossary

This glossary contains a number of terms that are associated with the State Planning System. The index which follows provides references to the SPS documents for these terms as well as for other terms that are not listed here.

Constant Value (K). An SPS variable type used to store values that are fixed throughout a run of SOM.

Control Variable (C). An SPS variable type used to store values that may be modified by SOM if an optimization run is made.

Data and Report Module (DRM). The data manager and report writer for the SPS. DRM can create the data base and description file used by SOM and can produce tables or plots of the results of one or more runs of SOM. Other uses of DRM are to: (1) produce summaries of the data base and description files, (2) produce a listing of the design file values, (3) produce update files to modify data values before a run of SOM, (4) write subsets of data base or description files, (5) produce files used to modify existing data base or description files, and (6) sort small data base or description files.

Data Base File (DB). A file which contains all the data values used by a design. Each data value is identified by the time period, variable type and index, sector, and run number associated with that value.

Description File (DC). A file which contains all the labels (descriptions) used to identify the output of an SPS design. These labels are provided by the user to identify each variable used in a design.

Design. The overall set of relationships, data identifiers, and control parameters used in an SPS application.

Design File (DF). A file which provides the definition of an SPS design. The design file describes the number of variables, number of planning periods, basic design characteristics, and labels of a design.

Design Subroutines File (DS). A file which contains the actual relationships used in an SPS design. The design subroutines (consisting of three FORTRAN subroutines with a standard calling sequence, STATE, TERMS, and MSRS) are provided by the user. These routines are called by SOM when making a run.

Dynamic Variable (D). An SPS variable type used to store computed values that flow from one time period to the next.

Exogenous Value (E). An SPS variable type used to store values that are fixed throughout a run of SOM.

Index. A key used to identify a variable of a given type; each variable in an SPS design is identified by its SPS variable type and by an index value. For example, control variables one, two, three, four, etc.

INTABL. The standard instruction table file which must be provided for each run of SOM and DRM.

Key. An identifier used in the SPS to identify records and link file types together. The six SPS keys are: design, run, sector, type, index, and time.

Lagged Data References. The incorporation of historical data values in design equations.

Lower Bound (L). An SPS variable type used to store the lower bound for its associated control variable.

Measure Variable (M). An SPS variable type used to store values, calculated within a time period, that are used only for reporting purposes.

Merge Module (MRG). The file merger for the SPS. MRG can append the results of several runs of SOM together so that DRM can be used to produce reports comparing the runs. MRG can also modify existing data base or description files by merging them with special modification files produced by DRM.

Modify Data Base File (MDB). A small data base file created in DRM and used with MRG to modify an existing data base file.

Modify Description File (MDC). A small description file created in DRM and used with MRG to modify an existing description file.

MSRS Subroutine. The standard routine used to compute the measure values in the design subroutines file.

New Data Base File (NDB). The new data base file created by a run of SOM, DRM, or MRG.

New Description File (NDC). The new description file created by a run of DRM or MRG.

Optimization. The capability of SOM to adjust the control variables in a design to bring the term variables closer to their target values.

Print Switches. Values on the design file that are used to control the output produced by SOM.

Report File (RP). The output file of reports produced by SOM. It can be saved for later listing on a terminal or a line printer.

Run Number. The key value used to identify each data base produced by a run of SOM.

Run-Time Updates. Temporary modifications to certain design file values that are made during the course of a run of SOM.

Scale Factor (A). An SPS variable type used to store the scale factor for its associated control variable.

Sector. A grouping of data in an SPS design corresponding to one component of the design (e.g., a particular institution or a set of similar institutions). They are distinguished from each other by the sector key.

Sector Communication Table (SCT). *The specification of the data values that* are to be passed from one sector to another during a run of SOM. Unlike the DS, DB, DC, and DF files, the sector communication table file is not used with every SPS design.

Simulation. The capability of SOM to calculate the static, dynamic, term, and measure values for all the time periods in a design.

Simulation and Optimization Module (SOM). The computational module for the SPS. SOM is used for either simulation or optimization runs with the designs specified in the SPS data files. SOM produces certain standard reports on request and a new data base file containing the results of the current run.

STATE Subroutine. The standard routine used to compute the dynamic and static values in the design subroutines.

Static Variable. An SPS variable type used to store values computed within a time period.

Subdesign. The relationships and characteristics of an SPS design that apply to at least one sector. There may be several subdesigns in an SPS design and they are distinguished by the design key.

Subroutine. A unit of FORTRAN computer code that makes up part of a complete program. The user supplies the three design subroutines to SOM for each SPS design.

Target Value (T). An SPS variable type used to store the goal or desired value of its associated term variable.

TERMS Subroutine. The standard routine used to compute the term values in the design subroutines.

Term Variable (R). An SPS variable type used to store the calculated value of a design objective within a time period.

Time Period. The units of time in an SPS design. The values are determined by the user (that is, the time periods can be academic years, fiscal years, semesters, etc.) and are distinguished by the time key.

Update File (UP). The file used as an update to the data base during a run of SOM. It is created as an NDB file in DRM.

Upper Bound (U). An SPS variable type to store the upper bound for its associated control variable.

Variable Types. The set of twelve allowable variable types used in constructing a design for the SPS.

Weight Value (W). An SPS variable type used to indicate the relative importance of its associated term variable in a design.

Index

This index combines entries for all 12 State Planning System documents. Each entry is followed by a subentry for each document that contains a reference to that subject. The documents are abbreviated in the subentries as follows:

I	*Introduction to SPS*
M	*Modeling and SPS*
CS	*SPS Case Studies*
DP	*SPS Data Procedures*
DG	*SPS Design Guide*
GTM	*SPS General Training Manual*
ISTM	*SPS In-State Training Manual*
OG	*SPS Operation Guide*
SD	*SPS Software Documentation*
SIG	*SPS Software Installation Guide*
SOI	*SPS Summary Operating Instructions*
TC	*Theoretical Concepts Used in SPS*

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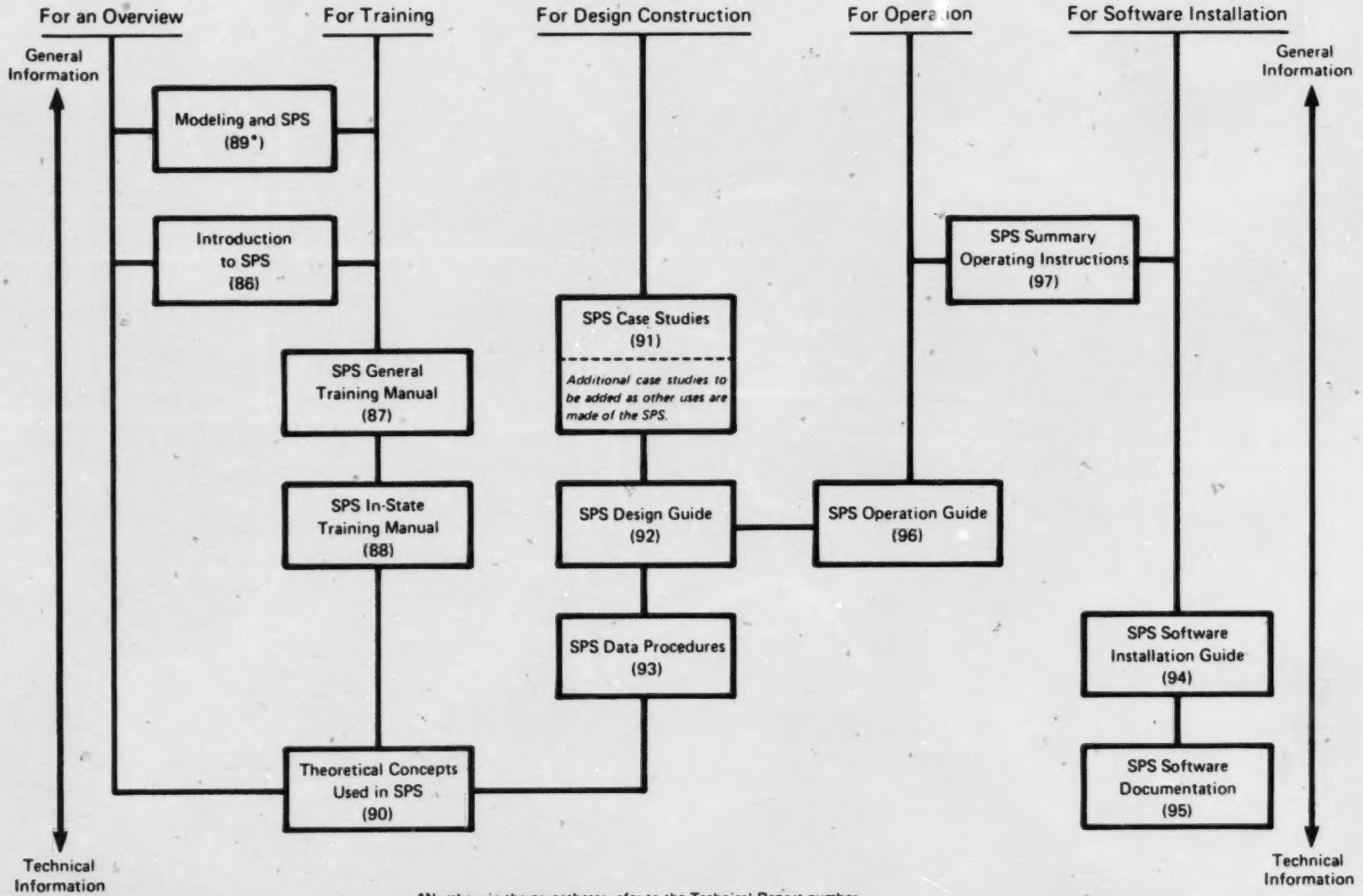
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SPS Case Studies (91)
Additional case studies to be added as other uses are made of the SPS.
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SPS Data Procedures (93)
SPS Summary Operating Instructions (97)
SPS Operation Guide (96)
SPS Software Installation Guide (94)
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